characters) practically invisible, has occurred without exciting especial comment. R. Greef, in the paper to which I have referred, gives what I take to be a very brief description of the process of aggregation in *Epistylis flavicans*, and, looking back at observations made on the digestive processes in *Amœba* some time ago, I feel that many which were puzzling then are in harmony with the experimental results recorded above. Among these I may instance the very sudden quiescence after enclosure of such small organisms as monads, the firm union of unlike ingesta which were by chance enclosed together and so came to be in a common vacuole, and the cohesion after ingestion of particles of carmine or Indian ink.

And if further work should replace these scattered points of likeness by fuller, harmonious observations, then I think that the process of aggregation, owing the interest which it possesses, not to the obvious movement of particles, but to the more hidden mechanism which carries out the movement, may be allowed to have some such functional value as that indicated in *Carchesium* by the constancy of its duration and the constancy of its occurrence, whatever the chemical nature of the foreign particles involved. It may perhaps rank as an expression of what has been lacking among the Protozoa—what is clear enough among Cœlenterata, with their well-defined, unicellular glands—as an expression of *obscure histological change bound up with the digestion of food, or more nearly with its preparation for digestion.*

II. "The Action of Light on Bacteria. III." By H. Marshall Ward, D.Sc., F.R.S., Professor of Botany, Royal Indian Engineering College, Coopers Hill. Received December 14, 1893.

(Abstract.)

Several observers, notably Arloing, Janowsky, Geisler, and Chemelewsky, have tried to determine which rays of the spectrum are chiefly concerned in the destruction of bacteria, but all attempts hitherto have been made by placing separate tubes of broth, gelatine, or potato cultures in the various regions of the spectrum, and judging of the relative rates of growth by the periods in which turbidity is apparent, or by the sizes of the respective growths on solid cultures, and their conclusions vary considerably.

The author has succeeded in obtaining photographic records by throwing the spectrum on an agar film evenly charged with the spores or bacilli to be investigated, and then observing the behaviour of the illuminated regions after incubation.

Various species have been employed, *Bacillus anthracis*, *B. sub-*

tilis, a violet bacillus from the Thames, and several other Thames bacilli being the chief.

In all cases so far examined, both the solar and electric spectra show that no action whatever is perceptible in the infra-red, red, orange, or yellow region, while all are injured or destroyed in the blue and violet regions.

The exact point when the action begins and ends is not the same in all the experiments, though very nearly so, but it must be reserved for the detailed memoir to discuss the various cases.

Broadly speaking, the action begins at the blue end of the green, rises to a maximum as we pass to the violet end of the blue, and diminishes as we proceed in the violet to the ultra-violet regions (fig. 1).

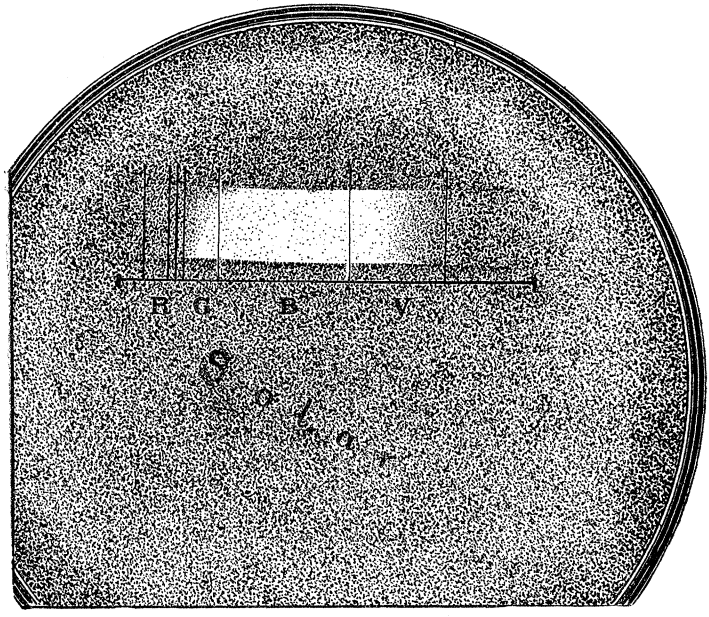


FIG. 1.—Plate of anthrax spores, exposed for five hours to the solar spectrum in August, and incubated for forty-eight hours. The spectrum shone on the plate through a slot of the width shown by the cleared portion, and whose length is denoted by the base line above the letters. The letters mark the principal regions of the spectrum; the vertical lines, the limits of these regions (not Fraunhofer's lines). Thus, those radiations we call infra-red, red (R), orange, and yellow affected the spores no more than total darkness, and colonies, therefore, germinated out in those regions as readily as over the main area of the plate. The same is partly true of the green (G) and the violet and ultra-violet regions to the right of V. The maximum effect is in the blue and blue-violet (BV), where nearly every spore has been destroyed, and the area appears cleared of colonies.

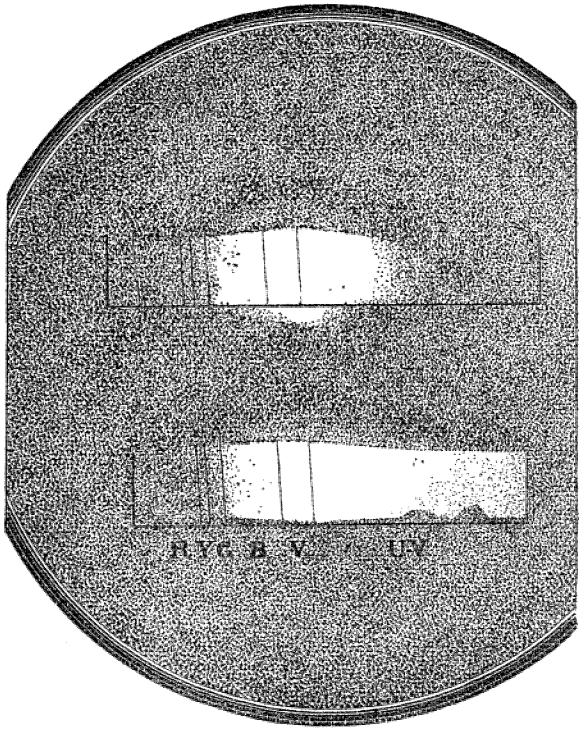


FIG. 2.—Plate similar to fig. 1, but exposed to the electric spectrum (obtained by means of quartz apparatus) for twelve hours, and incubated four days. The lower slot was covered with quartz only, the upper with a thin plate of glass. The base-line in each case gives length of exposed slot. In both cases the spores were uninjured in the infra-red, red (R), orange-yellow (Y), or green (G). The maximum effect was in the blue-violet, and it is interesting to see how the bactericidal action extended far into the ultra-violet (UV) in the case of the lower slot, where the light passed through quartz only. The two little protuberances over UV were due to two little overflows of burnt Canada balsam at the edge of the slot, cutting off light.

Some especially interesting results were obtained with the electric spectrum.* In the first place, the results with glass prisms,

* The author records his thanks to his colleagues, Professor Stocker and Mr. Shields, and to Drs. Woodhead and Cartwright Wood, for enabling him to try a few preliminary exposures to the electric lantern last winter and spring; these yielded no results, however, and it was not until he was so fortunate as to secure the hearty cooperation of Professor Oliver Lodge that it was possible to accomplish the photographing of the electric spectra in bacteria. To Professor Lodge and Mr. E. Robinson the author takes this opportunity of expressing his special thanks for the continuous pains they have taken to have his plates properly exposed. The

lenses, &c., were so feeble that it was necessary to employ quartz throughout.

Secondly, the bactericidal effect is found to extend far into the ultra-violet. The intervention of a thin piece of glass results in the cutting off of a large proportion of effective rays (fig. 2).

Thirdly, the most destructive rays—end of blue and beginning of violet—are to some extent effective even after reflection from the inner faces of the quartz plate covering the film and the glass on which it is supported, and so a peculiar bellying out of the image of the illuminated slot is observable during the early stages of incubation—the figure being thus made to show its own curve of intensity as it were.

The plates employed are ordinary agar cultures in shallow glass dishes, covered with a glass plate in which one or more slots—about 3 ins. long by $\frac{1}{2}$ in. wide—are pierced. Over the slots a quartz plate is secured, and all covered with black paper and foil, except the slots. The exposures are made on ice.

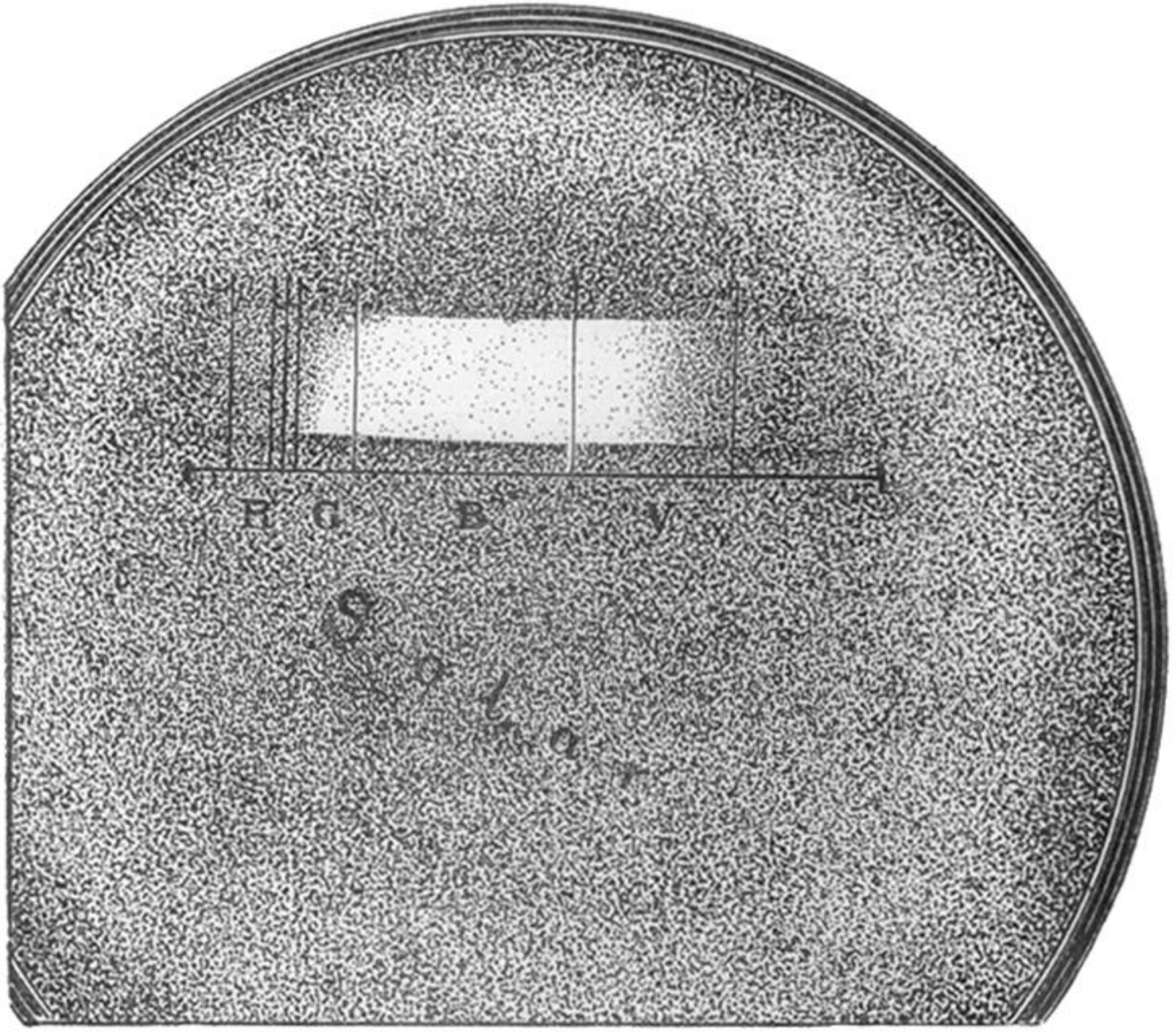
The author is also using plates divided in two halves, so that two similar films containing bacteria of different species can be exposed simultaneously to the same spectrum.

These results suggest evidently that the naked arc light may prove to be a very efficient disinfecting agent in hospital wards, railway carriages, or anywhere where the rays can be projected directly on to the organism. The author has elsewhere shown the evidence on which it is concluded that the action is direct and on the cell contents ; but even if the action took place at the surface of the cells, the above conclusion would still be true in practice.

It is extremely desirable that experiments should be made on the action of light on living cells of animals—*e.g.*, Infusoria, ova, &c—since results would probably be obtained of importance as regards sunburn, sun-baths, and other matters.*

exposures to the solar spectra were made by the author himself, and he is indebted to Professors McLeod and Stocker for the use of apparatus and for valuable advice.

* Raum, in 'Zeitschr. f. Hygiene,' 1889, has collected some literature bearing on this subject.



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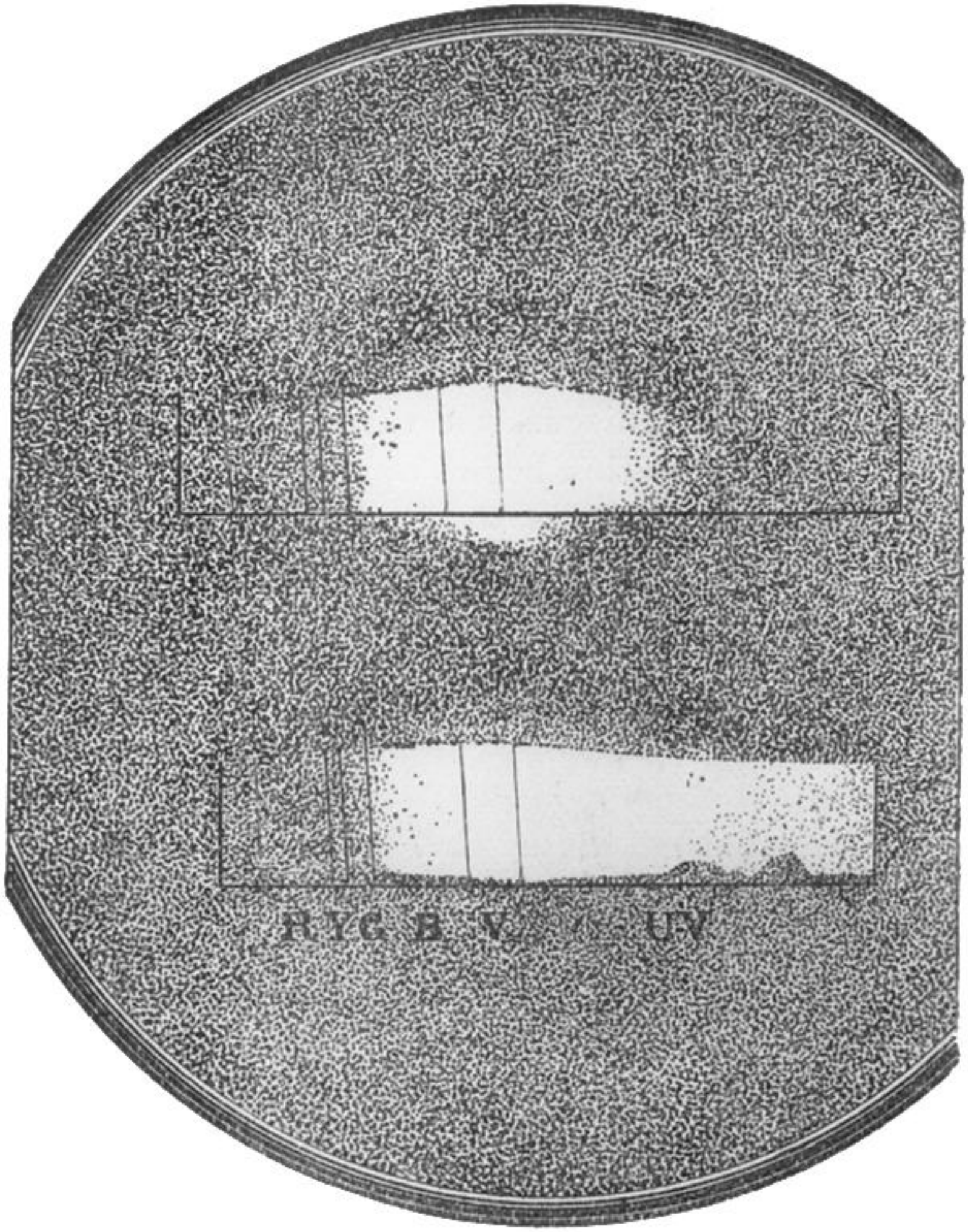

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